

Unlicensed Mobile Access (UMA) Handover and Packet Data Performance Analysis

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Abstract

UMA is a technology helping cellular operators to retain control over subscribers in the era of converging radio access technologies. By supporting handovers to and from WiFi networks, UMA seems to be a perfect solution as new mobile services require performance and seamless mobility. From the cellular operator point of view UMA does not require enormous investments and is a good choice for extending network coverage. This research paper discusses the technical implications of UMA based on measurement results for GSM to WiFi handovers and packet data performance. The measurements show that UMA works well, and voice handover breaks are similar or lower than those experienced in traditional GSM systems. In addition, UMA provides a considerably higher throughput than GSM systems. The results showed that the average throughput is twice or more than in GSM. Therefore, the user experience for data services improves to 3G-kind of services.

Keywords: UMA, handovers, mobility, WiFi

1. Introduction

There is an ongoing emergence of various radio access technologies that provide interesting technical solutions to offer new services through other than cellular access. New radio access technologies might provide higher throughput, and they also ease the load of cellular access networks. The possibility of using e.g. home WiFi routers or public WiFi hotspots with the same handset, provides a challenger alternative to cellular access, and thus an access to general Internet services without the operator restricting or managing the ownership of the customer. This is the core of the disruptive potential of actors such as Skype, who are planning a mobile entry.

However, cellular network operators are still in a key position in the business, and they can leverage on

the substantial subscriber domain and associated network externalities, economies-of-scale in billing etc. Furthermore, cellular network operators have also technologies which might maintain their power positions in the game. In particular, the UMA (unlicensed mobile access) technology provides a way to access the core GSM network through WiFi. This sounds attractive from the point of view of cellular network operators, who could thus extend their network coverage through WiFi hotspots with minimal additional investment. Improving coverage (especially indoors) is of great importance in some countries where adequate GSM coverage indoors and throughout some other areas in the country is not yet available. The United States and Japan are good examples of countries lacking consistent coverage indoors. With UMA, the operator still manages the core network. Radio access technologies on the edge of the network are only used as kind of platforms for packet-switched tunneling of either circuit or packet-switched connections to the operator's network.

This research paper discusses the UMA technology in detail, after which technical performance measures of the technology are considered. The paper sets out to technically address whether UMA could work in real life situations. Focus is put on the handover and packet data performance of UMA compared to current cellular networks. Based on the measurement results conclusions are presented.

2. UMA Overview

The core idea of UMA is to provide an access to the operator's network through not only cellular, but also through unlicensed radio access technologies such as WiFi. Originally, UMA was developed to provide an access to GSM/EDGE networks through unlicensed radio access points. The technology, however, is nowadays developed in the 3GPP consortium under the name GAN (generic access network), which also considers the link to WCDMA[3]. Despite the official

name being changed to GAN, UMA is used quite a lot as it was the name with which the idea became public and familiar in the industry.

The principle for UMA is the possibility to tunnel connections over unlicensed radio access technologies back to the operator's network. UMA also supports seamless handovers between cellular and WiFi. This new technology provides a means to extend coverage through e.g. cheap WiFi access points instead of expensive cellular base stations. UMA could thus decrease the load of legacy GSM access networks. At the same time the operator still holds control over the connection, and therefore can charge upon that. The possibility to use e.g. WiFi could, however, also reflect in connection prices, as WiFi hotspots are much cheaper to deploy than GSM base stations. The key question is naturally whether the same or different operator owns the WiFi access network than cellular network.

The UMA solution does not need much direct investments. The most critical point is a UMA network controller (UNC), which provides authentication and tunneling setup. In the UNC operators can also specify other restrictions for the access, such as access point SSID or MAC specifications. Therefore, the cellular network operator (who also runs the UMA solution) can specify who can use UMA and how they can use it in connecting to the operator's core network. The generic structure of the UMA access system is illustrated in Figure 1.

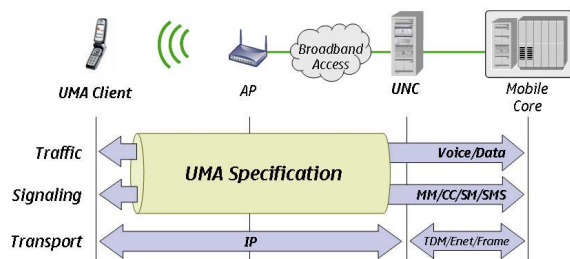


Figure 1. UMA access to cellular network

UMA provides a variety of security mechanisms, too. For example in the authentication IKEv2 and EAP-SIM/EAP-AKA solutions are used between the MS (mobile station) and UNC. These solutions leverage on the SIM card installed in the handset. Once again this looks good from the operator point of view, as they are the ones who provided SIM cards and therefore literally own the customer. IPsec, is used to create a secure tunnel in which both traffic and signaling is transported between the MS and the UNC.

UMA provides four possibilities to manage/prioritize cellular and unlicensed access networks:

- GSM-only
 - MS stays in GSM mode; normal GSM procedures apply
- GSM-preferred
 - If no GSM PLMN available, and if UMA coverage detected, MS switches to UMA mode
 - When GSM PLMN becomes available, or if UMAN coverage is lost, MS switches back to GSM mode
- UMA-preferred
 - When UMA coverage is detected, the MS switches to UMA mode
 - When UMA coverage is lost, the MS switches to GSM mode
- UMAN-only
 - MS switches to UMA mode after power-up sequence (even before UMA coverage is detected)

From the technical point of view, all in all, UMA is thus effectively an extension of GSM to the unlicensed spectrum, while at the same time, it provides a way to control the customer and direct the traffic back to the operator's own network.

3. UMA Access and Handovers

The UMA cell is analogous to a GSM base station controller (BSC). For that reason, it is perceived as such by the cellular network and roaming between UMA and GSM is considered an inter-BSC handover. From the BSC perspective the UNC is just another BSC. In theory, if the UNC is in the BSC neighbors list, it is possible to perform a handover. However, the individual WiFi cells are independent from the UMA system. Regardless of the similarities between the UNC and the BSC, the cell size does not directly correlate.

The UNC can cover any area from which it is accessible via a broadband connection. Such area can be e.g. an operator's broadband network or even the Internet. However, in order to perform handovers between the UMA and GSM systems, the UNC must be configured as a neighbor for the BSC in place. Furthermore, if the UNC is configured as the neighbor for several BSCs, a single UNC could cover a wide area of GSM coverage. Since broadband connectivity can occur from many locations, several access restriction mechanisms to UMA exist. For example, the MS can be required to be in an overlapping GSM cell owned by the cellular operator in order to access UMA [1].

3.1. GSM-UMA Mobility

Handovers between the GSM and UMA systems are in most of the cases originated by the MS. Depending on the operating mode, the MS will decide how often it will attempt to establish a connection and/or start a handover. The handover triggers are likely to be based on received signal strength measurements. However, the standard also provides the means to originate the handover based on a request from the UNC.

In the case of GSM-to-UMA handovers, the message flow is depicted in Figure 2 [11]. The initial state before the handover requires that the call is active in the GSM system. That is, voice goes through the BSC and then to the core network (CN). Afterwards, while the GSM call is ongoing, four main stages take place. First, when the MS detects WiFi, it will establish a link with the access point and attempt to establish a secure IPsec tunnel with the UNC. The establishment of the secure tunnel requires the mobile station to be authenticated by the UNC. This procedure is known as UMA registration. Second, the mobile station initiates the handover by reporting a UMA neighbor cell as the highest signal level to the BSC. Assuming that the operator's BSS is configured with the UMA cell as a neighbor, the source BSC decides to start the handover procedure based on the handover report. The handover procedure between the source BSC, core network and UNC follows the same signaling flow as the GSM inter-BSC handover. It is not explicitly visible to the source BSC that the target handover is the UMA access. Once the signaling required for the handover has taken place, a handover command message will be sent to the MS indicating that the handover can take place (messages 1 to 6). Third, the MS will start the actual handover between systems. This procedure involves two main phases, one to setup a voice stream connection (messages 7 to 9), and another phase to transfer the voice stream from the GSM access to the UMA access. The actual voice break resulting from the handover will happen only in this second phase of the handover (messages 10 to 12). Fourth and last, the previous connection is released from the GSM system (messages 13 to 14).

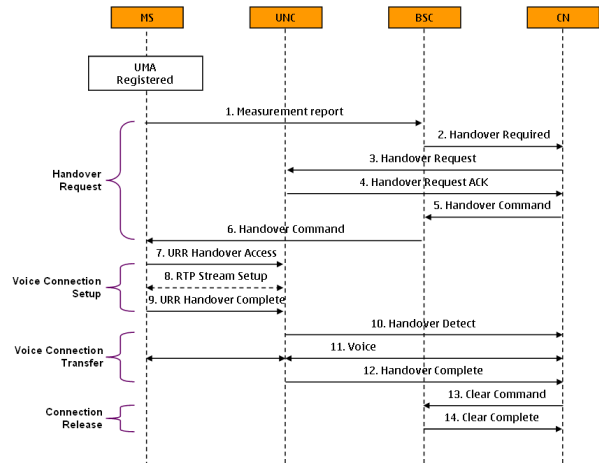


Figure 2. GSM-to-UMA Handover Procedure

The message flow for UMA-to-GSM handovers is depicted in Figure 3 [11]. The initial state before the handover requires that the call is active in the UMA system. That is, voice goes through the UNC and then to the core network. Whilst the UMA call is ongoing, three main stages take place. First, when the WiFi link is deteriorated up to a predefined threshold, the MS determines that the WiFi link is no longer acceptable for UMA service. However, it is also possible to trigger the handover via an uplink quality indication message from the UNC. At this point, the MS sends a handover required message to the UNC specifying the signal levels of the neighboring GSM cells. Subsequently, the UNC selects one of the target cells and sends a handover request to the core network. The core network then handles the resource allocation procedures with the BSC for the GSM call. Once the resources have been allocated, the MS is notified that the handover is ready to take place (messages 2 to 7). Second, the MS will start the actual handover between systems. This procedure involves two main phases, one to setup a voice stream connection (messages 8 to 11) and another to transfer the voice stream from the UMA access to the GSM access (messages 12 to 14). The actual voice break resulting from the handover will happen only in this second phase of the handover. Third and last, the previous connection is released from the UMA system (messages 15 to 18).

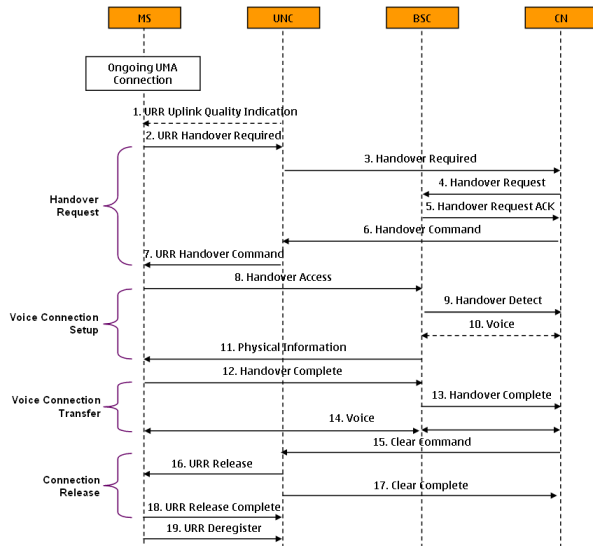


Figure 3. UMA-to-GSM Handover Procedure

3.2. UMA-UMA Mobility

UMA-UMA mobility is out of the scope of the UMA standards. Therefore, the functionality is based on traditional WiFi handover mechanisms. As a consequence, all the mobility issues encountered in common WiFi deployments exist in UMA as well. For informational purposes the UMA-UMA handovers are described in this section as well as some of the problems that could be encountered.

Handovers in WiFi are designed in such a way that clients will attempt the handoff until the link quality is considerably deteriorated. This is a problem when continuous coverage is built because the client will not attempt to change the cell even when there is a cell that provides better signal strength. This ends up in very late cell changes, poor voice quality and dropped connections. Furthermore, in some cases, even if the handover break is short, the perceived voice quality can be poor for several seconds for several seconds due to the low signal quality prior to the handover. Additionally, some access points (AP) may have a considerably higher load than a subsequent AP even though they overlap in coverage. In the case of roaming in different subnets, the client will need to re-authenticate with the new subnet, which results in longer delays. To address handover times and roaming several methods have been developed but in practice they are not widely implemented nor supported by current devices. [4][5][6]

Handovers in WiFi are even more problematic in scenarios in which background data is present. The presence of data will impact the ability of the voice packets to get access to the channel regardless of its priority level. As the amount of data traffic increases,

the probability that a user can access the medium in the time required to maintain toll-quality voice is diminished proportionately. If it takes too long for a client to gain access to the channel, it will lead to an unacceptable voice delay. Channel access delay plays a direct role in handovers because constant associations and re-associations might be required [10]. Laboratory test results in [9] show that handovers between APs only have low delays when there is no background data. However, the presence of background data increases delays considerably.

4. Testbed and Methodology

The mobility performance of the UMA system between GSM and UMA handovers was tested with the environment setup depicted in Figure 4. The testing methodology consisted of establishing a voice call and afterwards moving in and out of the UMA coverage by physically moving away and towards the access point. All the measurements were carried out in an indoor environment. Several iterations of this method were carried out, and differences in speed between movements in and out of the UMA coverage were taken into account. In order to measure handover times, signaling was captured from three interfaces in the network. Nethawk GSM Analyzer [8] was used to capture packets in the "A" interface between the core network and the UNC, and the "A" interface between the core network and the BSC. Additionally, Wireshark Protocol Analyzer software [12] was used to capture packets in the interface between the UNC and the UMA client.

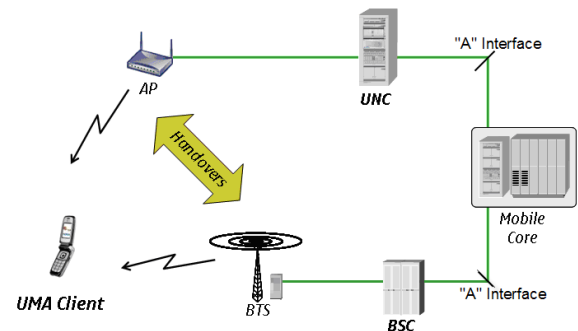


Figure 4. UMA Test Environment

The accuracy of the captured measurements would be improved if packet captures were performed at the ends of the network. That is, directly from the MS WiFi and GSM interfaces directly. However, this would require specialized software in the MS and additional deciphering tools. Therefore, this approach is not feasible in practice.

Packet data performance tests consisted of multiple iterations of file downloads from a file server in the Internet (ftp.funet.fi). The server is known to have high speed bandwidth within Finland, where the tests took place. The files downloaded were of 2 and 4.2MB sizes respectively.

5. Measurement Results

The results of the measurements are analyzed and compared with the GSM system in sections 5.1 and 5.2.

5.1. Handover Performance Results

The results from the handover measurements carried out are summarized in Table 1 in accordance to the signaling phases described in 3.1.

Table 1. GSM-UMA Handover Measurements

	GSM-to-UMA	UMA-to-GSM
UMA Registration	442 ms	-
Handover Request	157 ms	290 ms
Voice Connection Setup	77 ms	62 ms
Voice Connection Transfer	27 ms	199 ms
Connection Release	10 ms	208 ms
Total Handover Time	271 ms	759 ms

It is important to note that the voice break that occurs due to the handover only takes place during the voice connection transfer. Furthermore, since the measurements were based on message capturing, the time between messages is not an absolute value for the voice break. Regardless of this, the measurements reveal that the possible voice break in UMA-GSM handovers are in line to typical breaks in GSM inter-BSC handovers (120-220ms)[2].

Likewise, the UMA software in the MS is likely to implement packet loss concealment algorithms. Packet loss concealment algorithms hide transmission losses in an audio system. Different algorithms exist and techniques such as packet substitution, prediction, silence suppression, and white noise can be implemented to deal with packet losses [7][13].

5.2. Packet Data Performance Results

The results from the packet data performance tests are summarized in the following equation.

$$\text{Average TCP Throughput} = 268\text{kbps}$$

The results show that even though UMA originally seemed to be a potential candidate for boosting data rates while WiFi coverage was available, the average throughput is not as high as expected. However, the average throughput of 268kbps is considerably higher than what is available via GPRS or EDGE in GSM networks. Current GSM and EDGE networks provide throughputs around 30kbps and 120kbps respectively. UMA data throughput is in fact, very similar to the data rates available in WCDMA (3G) networks. Therefore, UMA technology is able to improve the user experience and performance for data services from GPRS or EDGE to WCDMA-like kind of service. From the operator's point of view, this means UMA can provide an additional value to its current services with a minimal investment.

The reason the very high WiFi data are not possible is due to several factors both in the wireless network and the mobile terminal. Some of the current bottlenecks that we have detected that can limit data performance are:

- Mobile Terminal processing power
- Gb interface (between UNC and SGSN), which is normally based on T1 lines with a maximum bandwidth of 2Mbps to be shared among all subscribers served by the UNC.
- Subscriber's data throughput limit defined in the Home Location Register by the operator. This limit is usually assigned based on the service subscription type and can vary from very low rates such as 64kbps to several Megabits (e.g. 8Mbps for HSDPA subscribers).
- GPRS theoretical data limit, which is around 600kbps.

6. Conclusion

The technical measurements of UMA performance provided evidence that the solution really works. The handover times between UMA and GSM are similar to typical inter-BSC handovers in the GSM system. Therefore, UMA is at its best in extending the cellular network operator's current network coverage in indoor locations. Ceteris paribus, the poorer the initial indoor cellular reception and possibilities to extend GSM coverage, the more attractive it would be business-wise to deploy UMA. Likewise, UMA allows the operator

to improve the user experience for data services from GSM to 3G-like kind of services due to the higher throughput available in UMA. The measurements showed that throughput is twice or more than the data rates available in GSM networks. The promising measurement results suggest that there is a lot of potential to extend network coverage and deploy hotspot kind of access points in special circumstances. At the same time, the cellular network operator holds control over subscribers and traffic flows.

7. References

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